



# **REPORT ON THE AQUATIC PLANT COMMUNITY OF BIG ROCHE A CRI LAKE**

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## Executive Summary

Big Roche-a-Cri Lake is a mesotrophic lake with good water quality and fair-to poor water clarity. Filamentous algae is common in the 0-1.5ft depth zone; thick films of planktonic algae is common throughout and abundant in the 0-10ft depth zone.

The aquatic plant community colonized more than three-quarters of the littoral zone to a maximum depth of 13 feet with the most abundant plant growth in the 0-5ft depth zone. The aquatic plant community is also characterized by below average quality, good species diversity, and a high tolerance to disturbance, the result of past disturbance.

*Ceratophyllum demersum* is the dominant species within the plant community, especially in the 0-1.5ft depth zone. *Vallisneria americana* was sub-dominant, especially near the dam. The exotic species, Eurasian watermilfoil, ranks third in abundance (tied with *Elodea canadensis*), and was found at more than one-third of the sites. Eurasian watermilfoil exhibited a growth form of average density and was most abundant west of Highway 13 in the 5-10ft depth zone.

A healthy aquatic plant community is important because that plant community improves water quality, provides valuable habitat resources for fish and wildlife, resists the spread of non-native species and check sexcessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

## Management Recommendations

- 1) Reinvolve the Lake District in water quality monitoring through the Self-Help Volunteer Lake Monitoring Program.
- 2) Chemical treatments for plant growth are not recommended in Big Roche-a-Cri Lake in the future due to the undesirable side effects of chemical treatments. the spread of the exotic species.
- 3) Restore natural shoreline restoration.
  - a) Shoreline restoration could be a as simple as leaving a band of natural vegetation around the shore by discontinuing mowing.
  - b) Restoration could be as ambitious as extensive plantings of attractive native wetland species in the water and native grasses, flowers, shrubs and trees on the near shore area.
- 4) Fine-tune the harvesting plan. Plan should be designed to remove nutrients, target Eurasian watermilfoil, provide navigation and recreation where appropriate, prevent the spread of species that could become overabundant and improve habitat.
- 5) Cooperate with programs in the watershed to reduce nutrient inputs to the lake. Currently nearly half of the relatively large watershed is in agriculture.
- 6) Eliminate the use of lawn fertilizers, both organic and inorganic, on properties around the lake.
- 7) Investigate the possibility of using periodic winter drawdowns to control Eurasian watermilfoil in the shallow zone.

# **The Aquatic Plant Community in Big Roche-a-Cri Lake, Adams County 2004**

## **I. INTRODUCTION**

A study of the aquatic macrophytes (plants) in Big Roche-a-Cri Lake was conducted during July 2004 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and a member of the Big Roche-a-Cri Lake District. This was the first quantitative vegetation study of Big Roche-a-Cri Lake by the DNR. Qualitative assessments were conducted in May 1964 by WI Water Pollution Committee staff and in 1996 by North Central Region staff - DNR.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation in the lake and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

**Ecological Role:** All other life in the lake depends on the plant life - the beginning of the food chain. Aquatic plants and algae provide food and oxygen for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants provide habitat, improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

**Characterize Water Quality:** Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The present study will provide information that is important for effective management of the lake, including fish habitat improvement, protection of sensitive wildlife areas, aquatic plant management and water resource regulations. The baseline data that it provides will be compared to past and future aquatic plant inventories and offer insight into any changes occurring in the lake.

**Background and History:** Big Roche-a-Cri Lake is a 218-acre impoundment on Big Roche-a-Cri Creek in north central Adams County, Wisconsin. Big Roche-a-Cri Lake has a maximum depth of 20 feet and an average depth of 9 feet. Big Roche-a-Cri Lake was formed in 1856 when a small dam was built on Big Roche-a-Cri River to form a mill pond of unknown size for operating a grist mill. Today's lake was formed when a new, larger dam was constructed on the same site in 1926 for power generation.

A watershed analysis of Big Roche-a-Cri Lake determined that its watershed is 45,445 acres and that phosphorus loading to the lake from the watershed was approximately 826 pounds per year (Foth and Van Dyke, 2000). The size of the watershed means that the lake to watershed ratio is 208:1. Lakes with a watershed to lake ratio greater than

10:1 tend to have water quality problems (Field 1994).

**Table 1. Big Roche-a-Cri Lake Watershed, 1993.**

<b>Land Use</b>	<b>Acres</b>	<b>Percent of Total Acreage</b>	<b>% of Phosphorus contribution</b>
<b>Agriculture</b>	14,053	31%	56%
<b>Forest</b>	13,344	29%	18%
<b>Open Space</b>	11,574	26%	15%
<b>Wetlands</b>	5,717	13%	8%
<b>Residential/Urban</b>	758	2%	3%
<b>Surface Water</b>	512	1%	
<b>Total</b>	45,958		826#/year

A lake association was formed sometime during the 1930's or 40's. Complaints from lake users to the WI-DNR concerning aquatic plant growth are recorded as early as 1954.

There is a long history of chemical control of aquatic plants and algae in Big Roche-a-Cri Lake (Table 2). Multiple treatments were conducted in many years; in 1975 there were 10 treatments in one year. Up to one-fourth of the lake has been treated in any one year.

**Table 2. Herbicide Applied to Big Roche-a-Cri Lake**

	Arsenic Trioxide (lbs.)	Silvex 2,4,5-TP	2,4-D (gal.)	Cutrine (gal.)	Copper Sulfate (lbs.)	Diquat (gal.)	Endothall	Area Treated (acres)	# Treatments
1959	3720							33	2
1960	5220							47	
1962	4500							30	2
1963	1620							12	2
1964	2000							16	2
1965	1200						7.2g. 1200#	6	
1966	2700	35					25.4g.	23	1
1970			20	87	189	30		70	4
1972							25#	0.1	1
1975			14		975	36.4	23.6g. 150#	50	10
1976					450	9.5	12.5g. 550#	14	6
1977			10		550	6	9g. 500#	30	4
1978			10		350	17	1150#	23	3
1983							1200#	5.3	1
1984							1320 #	7	1
1985							1400#	8	1
1986							1400#	12	1
1987							2000#	8	1
<b>Total</b>	20,960	35	44	87	2514	98.9	77.7gal. 10,895#		

Some herbicides that are problematic were used.

- 1) Arsenic is highly toxic. Between 1959 and 1966, more than 10 tons of arsenic was applied to Big Roche-a-Cri Lake (Table 2). Arsenic is no longer allowed as an aquatic pesticide because it is highly toxic to all species. Since it does not break down, arsenic stays in the sediments, resulting in the necessity to treat lake sediments as hazardous waste.
- 2) Another toxic compound used in Big Roche-a-Cri was Silvex (2,2,4,5-TP). Silvex is now banned as a possible carcinogen (Table 2).
- 3) Broad-spectrum chemicals have been used, Diquat and Endothall compounds. These compounds kill all plant species and inadvertently open up areas for the introduction of exotic and invasive species. Almost 100 gal of Diquat compounds had been used between 1970 and 1978. Endothall products have been applied as 1) 77 gallons of Aquathol between 1967 and 1977 and 2) more than 5 tons of Hydrothol between 1965 and 1987 (Table 2).
- 4) The Hydrothol formulation of Endthall is more toxic to young fish.
- 5) Cutrine and CuSO<sub>4</sub> are copper products that were used to kill algae and reduce swimmer's itch (Table 2). . Since copper is an element, it does not biodegrade further, building up the sediments. The drawbacks of copper treatments are:
  - a) the very short effective time



- b) the toxicity of copper to aquatic insects, an important part of the food chain in a lake
- c) the build up of copper in the sediments, resulting in sediments that are toxic to mollusks that are the natural consumers of algae in a lake.

During the late 1970's or early 1980's a small cutter was used by groups of association members to cut 4-foot paths for lake access where needed.

In 1988, Big Roche-a-Cri Lake Association formed the Big Roche-a-Cri Lake District and purchased a mechanical harvester. Mechanical harvesting began in 1988. Records of harvesting were sent to the DNR from 1993-1995 and 1998-2004 (Table 3). Records were not found for 1996-97. During those years for which there are records, over 5000 loads of aquatic plants, weighing more than 30 million pounds, have been removed from Big Roche-a-Cri Lake (Table 3). The removal of vegetation from the lake helps counteract nutrient inputs; however, impoundments can be impacted by ongoing inputs of nutrients.

**Table 3. Removal of Aquatic Vegetation by Mechanical Harvesting in Big Roche-a-Cri Lake, 1988 - Present**

	<b>Loads removed</b>	<b>Approx. weight of a load (pounds)</b>	<b>Approx. Weight (tons)</b>
<b>1988</b>	32	~6000	96
<b>1989</b>	250	7800	975
<b>1990</b>	216	6680	722
<b>1991</b>	287	6000	861
<b>1992</b>	210	6000	630
<b>1993</b>	260	6000	780
<b>1994</b>	193	6000	579
<b>1995</b>	125	6048	378
<b>1996</b>	208	6000	626
<b>1997*</b>	332	6000	996
<b>1998</b>	348	6000	1044
<b>1999</b>	358	6000	1074
<b>2000</b>	445	6000	1335
<b>2001</b>	325	6000	975
<b>2002</b>	509	6000	1527
<b>2003</b>	953	6000	2859
<b>2004</b>			963
<b>Total</b>	5051		16,420

\* - A second harvester was purchased, now two are operating.

Harvesting has generally started in Mid-May each year, sometimes as late as mid-June, and generally continues until late-September, sometimes as late as early October.

In 1996, the lake district produced a Lake Management Plan in order to purchase a second harvester. Recommendations were made to:

- 1) Protect the lake and watershed through town and county ordinances
- 2) Initiate a “Self-Help Monitoring Program” to obtain data annually on the lake
- 3) Reduce non-point source pollution through an education program and other measures
- 4) Protect water quality by developing an aquatic plant harvesting plan and purchasing a second harvester
- 5) The lake district also entered an agreement with native plant nurseries to remove wild celery tubers from the sediment to reduce the colonization of this species in the lake.

A survey of the residents during the planning process indicated that the most popular lake activity was fishing (88%); the largest perceived problem was aquatic plants (87%), requiring more aquatic plant removal (85%)

In 2001, the lake district contracted the University of Wisconsin – Eau Claire to produce an updated bathymetric map.

In 2003, Eurasian watermilfoil was found to have recently invaded Big Roche-a-Cri Lake. Like many exotic species, Eurasian watermilfoil is able to out-compete native species when introduced into a new area. Exotic species can dominate because the new environment does not usually support the diseases and herbivores that kept it in check in its native country.

## **II.METHODS**

### **Field Methods**

The study design was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random placement of transects. The shoreline was divided into 29 equal segments and a transect, perpendicular to the shoreline, was randomly placed within each segment (Appendix IV), using a random numbers table.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a long-handled, steel, thatching rake, four rake samples were taken at each sampling site, one rake sample from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. Each species was given a density rating (0-5), the number of rake samples on which it was present at each sampling site.

A rating of 1 indicates that a species was present on one rake sample

a rating of 2 indicates that a species was present on two rake samples

a rating of 3 indicates that it was present on three rake samples

a rating of 4 indicates that it was present on all four rake samples

a rating of 5 indicates that a species was abundantly present on all rake samples.

Visual inspection and periodic samples were taken between transect lines to record the presence of any species that did not occur at the sampling sites. Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet deep was evaluated. The percent cover of land use within this 100' x 30' rectangle was visually estimated.

### **Data Analysis**

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites) (Appendix I). Relative frequency was calculated (number of occurrences of a species/total occurrence of all species (Appendix I). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendix II). Relative density was calculated (sum of a species density/total plant density). A "mean density where present" was calculated for each species (sum of a species' density ratings/number of sampling sites at which the species occurred) (Appendix II). The relative frequency and relative density was summed to obtain a dominance value (Appendix III). Species diversity was calculated by Simpson's Diversity Index (Appendix I).

The Aquatic Macrophyte Community Index (AMCI) developed by Nichols et. al. (2000) was applied to Big Roche-a-Cri Lake. Measures for each of seven categories that characterize a plant community are converted to values between 0 and 10 and summed.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the Coefficients for all species found in the lake. The Floristic Quality Index is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.



### III. RESULTS

#### PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae, clarity and alkalinity) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also effect the macrophyte community.

**WATER QUALITY** - The trophic state of a lake is a classification of its water quality. Phosphorus concentration, chlorophyll concentration and water clarity data are collected and combined to determine the trophic state.

**Eutrophic lakes** are high in nutrients and therefore support a large biomass.

**Oligotrophic lakes** are low in nutrients and support limited plant growth and smaller populations of fish.

**Mesotrophic lakes** have intermediate levels of nutrients and biomass.

#### **Nutrients**

Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of the amount of nutrient in a lake. Increases in phosphorus in a lake can feed algae blooms and, alternately, excess plant growth.

**1995-2002 summer mean phosphorus concentration in Big Roche-a-Cri Lake was 23 ug/l at the dam end, 25.5 ug/l at mid-lake and 32.4 ug/l at the east end**

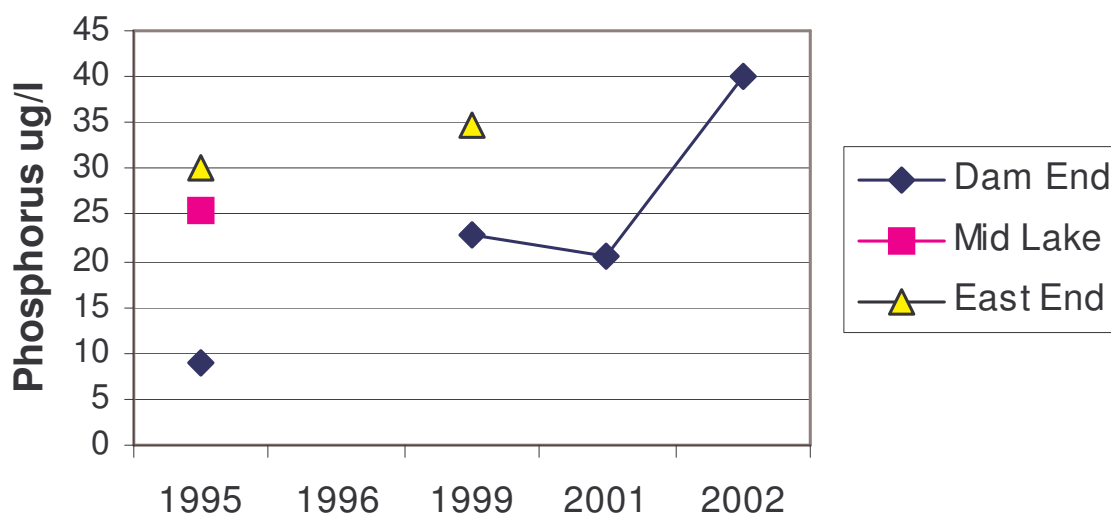
The concentration of phosphorus in the deeper, west basin of Big Roche-a-Cri Lake is indicative of a mesotrophic lake (Table 4).

**Table 4. Trophic Status**

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.
Oligotrophic	Excellent	<1	<1	> 19
	Very Good	1-10	<b>1-5</b>	8-19
Mesotrophic	Good	<b>10-30</b>	<b>5-10</b>	<b>6-8</b>
Eutrophic	Fair	<b>30-50</b>	10-15	<b>5-6</b>
	Poor	50-150	15-30	3-4
Big Roche-a-Cri Lake 1995-2002 Mean				
Dam End 1995-2002	Good	23	5.8	7.5
Mid-Lake 1995	Good	25.5	4.1	6.3
East End 1995-1999	Fair	32.4	2.1	5.9

After Lillie & Mason (1983) & Shaw et. al. (1993)

Phosphorus concentrations in Big Roche-a-Cri Lake have increased substantially during the years that data was collected (Figure 1). Phosphorus in Big Roche-a-Cri Lake increases spatially as the lake is sampled going upstream, with higher nutrient concentrations in the east end.



**Figure 1. Variation in mean summer phosphorus concentrations in Big Roche-a-Cri Lake, 1995-2002.**

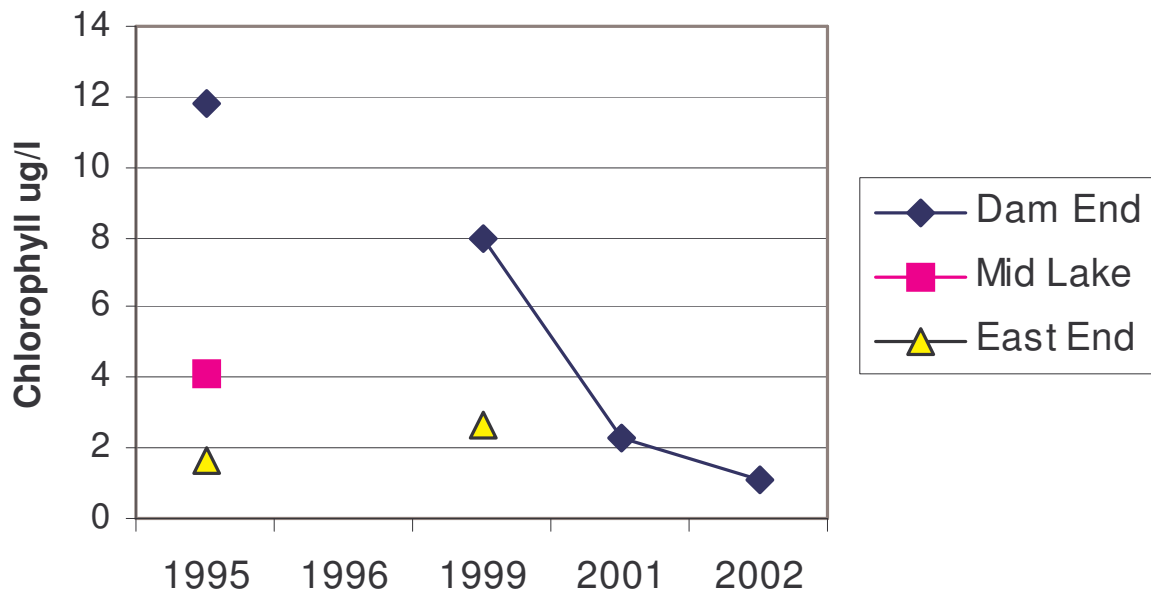
### Algae

Chlorophyll concentrations provide a measurement of the amount of algae in lake water. Algae are natural and essential in lakes, but high algae populations can increase turbidity and reduce the light available for plant growth.

**1995-2002 summer mean chlorophyll concentration in Big Roche-a-Cri Lake was 5.8 ug/l at the dam end, 4.1 ug/l at mid-lake and 2.1 at the east end.**

The chlorophyll concentration in the deep end of Big Roche-a-Cri Lake indicates that it was a mesotrophic lake (Table 4).

Chlorophyll decreases spatially as the lake is sampled going upstream. During 1995-2002, chlorophyll concentrations have decreased. The concentration of chlorophyll has decreased from mesotrophic, to oligotrophic (Figure 2).



**Figure 2. Chlorophyll concentrations in Big Roche-a-Cri Lake, 1995-2002.**

Chlorophyll often increases with increases in nutrients as the algae use the nutrients to multiply. Chlorophyll concentrations may have appeared to decrease in Big Roche-a-Cri in spite of increased nutrients. The excess nutrients may have been used for increased plant growth or increased growth of filamentous algae. The chlorophyll in filamentous algae are not measured during the sampling for planktonic algae.

Filamentous algae occurred at 18% of the sample sites. Filamentous algae occurred at:

- 26% of the sites in the 0-1.5ft depth zone
- 21% of the sites in the 1.5-5ft depth zone
- 17% of the sites in the 5-10ft depth zone
- 0% of the sites in the 10-20ft depth zone

Thick films of planktonic algae occurred at 37% of the sample sites. Planktonic algae films occurred at:

- 41% of the sites in the 0-1.5ft depth zone
- 38% of the sites in the 1.5-5ft depth zone
- 43% of the sites in the 5-10ft depth zone
- 20% of the sites in the 10-20ft depth zone

### Water Clarity

Water clarity is a critical factor for plants. When plants receive less than 1 - 2% of the surface illumination, they can not survive. Water clarity is reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color the water. Water clarity is measured with a Secchi disc that shows the combined effect of turbidity and color.

**Mean summer Secchi disc clarity in Big Roche-a-Cri Lake, 1989-2002, was 7.5 ft. at the dam end, 6.3 at mid-lake and 5.6 ft. at the east end.**

Water clarity indicates (Table 4) that Big Roche-a-Cri Lake was a mesotrophic lake with fair to poor water clarity.

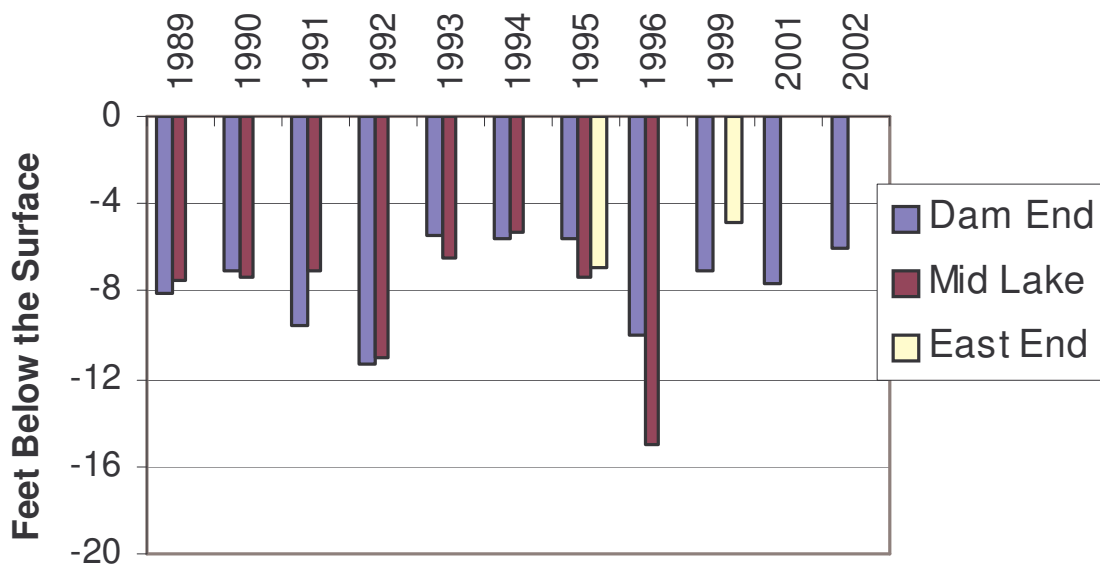
Volunteer lake monitors in the Self-help Volunteer Lake Monitoring Program have collected water quality data on Big Roche-a-Cri Lake.

T. Carter monitored water clarity 1989 and 1992.

Robert Anderson monitored water clarity 1989-1991

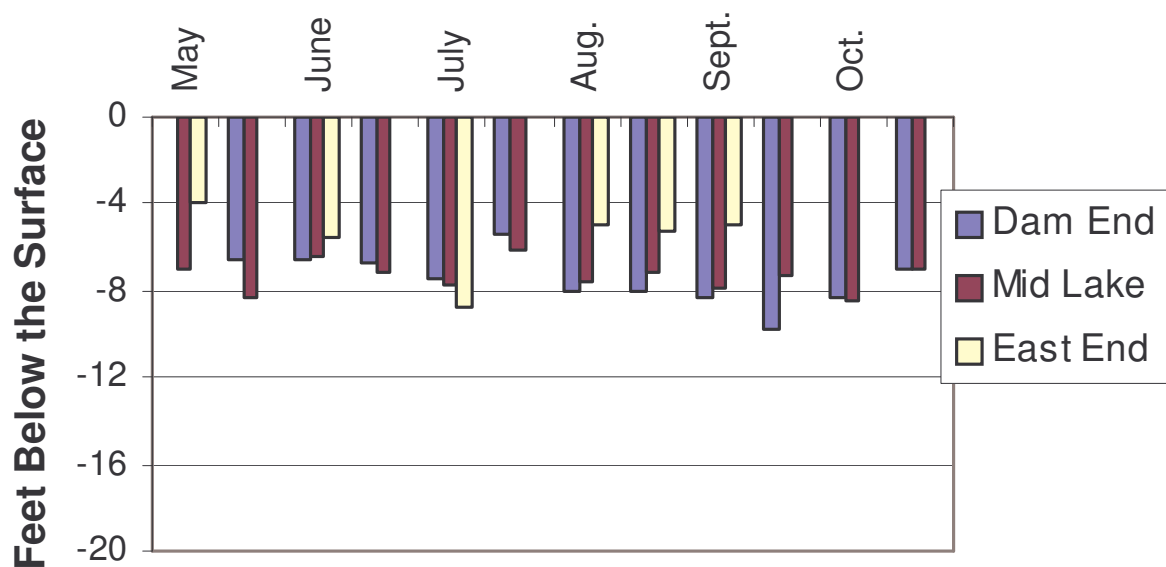
Gene Haffely monitored water clarity 1993-1996.

Water clarity decreased as the lake was sampled going upstream (Figure 3). The water clarity in Big Roche-a-Cri Lake has varied during 1989-2002, with the best mean clarity recorded in 1996 at mid-lake and the lowest clarity in 1999 at the east end (Figure 3). Clarity gradually decreased from 1989-2002 at the dam end. Variations in clarity can be the result of variations in algae growth in different years and turbidity after storm events.



**Figure 3. Variation in mean summer water clarity in Big Roche-a-Cri Lake, 1989-2002.**

Water clarity also varies during the growing season also (Figure 4).



**Figure 4. Variation in mean water clarity during the growing season in Big Roche-a-Cri Lake, 1989-2002.**

The combination of phosphorus concentration, chlorophyll concentration and water clarity indicates that Big Roche-a-Cri Lake is a mesotrophic lake with good water quality (Table 4). This trophic state would favor moderate levels of plant growth and occasional algae blooms.

#### **Hardness**

The hardness or mineral content of lake water can also influence aquatic plant growth. The 1999-2002 hardness values in Big Roche-a-Cri Lake ranged from 108-113 mg/l CaCO<sub>3</sub> in the moderately hard water range. (Lakes with hardness values of 61-120 mg/l CaCO<sub>3</sub> are considered moderately hard water lakes.) Hard water lakes tend to support more aquatic plant growth than soft water lakes.

**LAKE MORPHOMETRY** - The morphometry of a lake is an important factor in determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Big Roche-a-Cri Lake has a narrow basin with a gradually sloped littoral zone and shallow depths over most of the lake. Shallow depths and gradual slopes favor plant growth.

**SEDIMENT COMPOSITION** – The dominant sediment in Big Roche-a-Cri Lake

was sand, in all depth zones and throughout the lake (Table 5). No other sediment types were even common, at any depth.

**Table 5. Sediment Composition in Big Roche-a-Cri Lake, 2004**

<b>Sediment Type</b>		<b>0-1.5' Depth</b>	<b>1.5-5' Depth</b>	<b>5-10' Depth</b>	<b>10-20' Depth</b>	<b>Percent of all Sample Sites</b>
<b>Hard Sediments</b>	Sand	71%	61%	76%	87%	72%
	Rock	7%				2%
	Sand/Gravel		4%			1%
	Sand/Rock	7%				1%
<b>Mixed Sediments</b>	Sand/Silt		11%	5%	13%	6%
<b>Soft Sediments</b>	Silt		7%	19%		6%
<b>Sediments</b>	Muck	4%	14%			5%
	Silt/Muck	11%	4%			4%

**INFLUENCE OF SEDIMENT** - Some plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a location.

Silt sediments are intermediate density sediments. The availability of mineral nutrients for growth is highest in sediments of intermediate density (Barko and Smart 1986). Silt sediments and highly organic muck sediments supported plant growth at all sites in which they were found and more common in the east end of the lake.

Sand was the dominant sediment found in Big Roche-a-Cri Lake and may limit plant growth due to its high-density (Barko and Smart 1986), however 85% of the sites with sand sediment were vegetated (Table 6). The only sediments that were not 100% vegetated were other high-density, hard sediments.



**Table 6. Influence of Sediment in Big Roche-a-Cri Lake, 2004**

<b>Sediment Type</b>		<b>Percent of all Sample Sites</b>	<b>Percent of Sites Vegetated</b>
<b>Hard Sediments</b>	Sand	72%	85%
	Rock	2%	50%
	Sand/Gravel	1%	0%
	Sand/Rock	1%	100%
<b>Mixed Sediments</b>	Sand/Silt	6%	100%
<b>Soft Sediments</b>	Silt	6%	100%
	Muck	5%	100%
	Silt/Muck	4%	100%

**SHORELINE LAND USE** – Land use can strongly impact the aquatic plant community and therefore the entire aquatic community. Land use can directly impact the plant community through increased erosion and sedimentation and increased run-off of nutrients, fertilizers and toxics applied to the land. These impacts occur in both rural and residential settings.

Wooded cover was the most frequently encountered shoreline cover at the transects and had the highest mean coverage (Table 7). Other natural shoreline types (shrub and native herbaceous cover) were frequently encountered, as was, cultivated lawn, a disturbed shoreline type. Cultivated lawn also had a high coverage, 20%. Other disturbed shoreline types were also commonly encountered: hard structures, pavement and rip-rap.

**Table 7. Shoreline Land Use - Big Roche-a-Cri Lake, 2004**

Cover Type		Frequency of Occurrences at Transects	Mean % Coverage
Natural Shoreline	Wooded	86%	45%
	Native Herbaceous	59%	12%
	Shrub	52%	12%
Total Natural Cover			69%
Disturbed Shoreline	Cultivated Lawn	41%	20%
	Hard Structures	28%	4%
	Pavement	24%	4%
	Rip-rap	21%	3%
Total Disturbed Cover			31%

Some type of natural shoreline (wooded, shrub, native herbaceous) was found at 93% of the sites and had a mean coverage of 69% (Table7).

Some type of disturbed shoreline (cultivated lawn, hard structures and rip-rap) was found at 72% of the sites and had a mean coverage of 31% (Table7).

**MACROPHYTE DATA**  
**SPECIES PRESENT**

Of the 24 species found in Big Roche-a-Cri Lake, 7 were emergent species, 3 were floating-leaf species and 14 were submergent species (Table 8).

Two exotic species were found:

*Myriophyllum spicatum*

*Potamogeton crispus*

No threatened or endangered species were found.

**Table 8. Big Roche-a-Cri Lake Aquatic Plant Species, 2004**

<u>Scientific Name</u>	<u>Common Name</u>	<u>I. D. Code</u>
<u>Emergent Species</u>		
1) <i>Carex comosa</i> Boott.	bristly sedge	carco
2) <i>Cicuta bulbifera</i> L.	bulb-bearing water hemlock	cicbu
3) <i>Impatiens capensis</i> Meerb.	spotted jewelweed	impca
4) <i>Rumex</i> spp.	dock	rumsp
5) <i>Salix exigua</i> Nutt.	sandbar willow	salex
6) <i>Scirpus validus</i> Vahl.	softstem bulrush	sciva
7) <i>Typha latifolia</i> L.	common cattail	typla
<u>Floating-leaf Species</u>		
8) <i>Lemna minor</i> L.	small duckweed	lemmi
9) <i>Nuphar variegata</i> Durand.	bull-head pond lily	nupva
10) <i>Spirodela polyrhiza</i> (L.) Schleiden.	great duckweed	spipo
<u>Submergent Species</u>		
11) <i>Ceratophyllum demersum</i> L.	coontail	cerde
12) <i>Elodea canadensis</i> Michx.	common waterweed	eloca
13) <i>Myriophyllum spicatum</i> L.	Eurasian water milfoil	myrsp
14) <i>Najas guadalupensis</i> (Spreng.) magnus.	common water-nymph	najgu
15) <i>Potamogeton amplifolius</i> Tuckerman.	large-leaf pondweed	potam
16) <i>Potamogeton crispus</i> L.	curly-leaf pondweed	potcr
17) <i>Potamogeton illinoensis</i> Morong.	Illinois pondweed	potil
18) <i>Potamogeton natans</i> L.	floating-leaf pondweed	potna
19) <i>Potamogeton pectinatus</i> L.	sago pondweed	potpe
20) <i>Potamogeton pusillus</i> L.	small pondweed	potpu
21) <i>Potamogeton richardsonii</i> (Ar. Benn.) Rydb.	clasping-leaf pondweed	potri
22) <i>Potamogeton zosteriformis</i> Fern.	flatstem pondweed	potzo
23) <i>Vallisneria americana</i> L.	water celery	valam
24) <i>Zosterella dubia</i> (Jacq.) Small	water stargrass	zosdu

### FREQUENCY OF OCCURRENCE

*Ceratophyllum demersum* was the most frequently occurring species in Big Roche-a-Cri Lake in 2004, (72% of sample sites) (Figure 5). *Elodea canadensis*, *Lemna minor*, *Myriophyllum sibiricum*, *Potamogeton zosteriformis* and *Vallisneria americana* were also commonly occurring species, (39%, 20%, 42%, 25%, 62%).

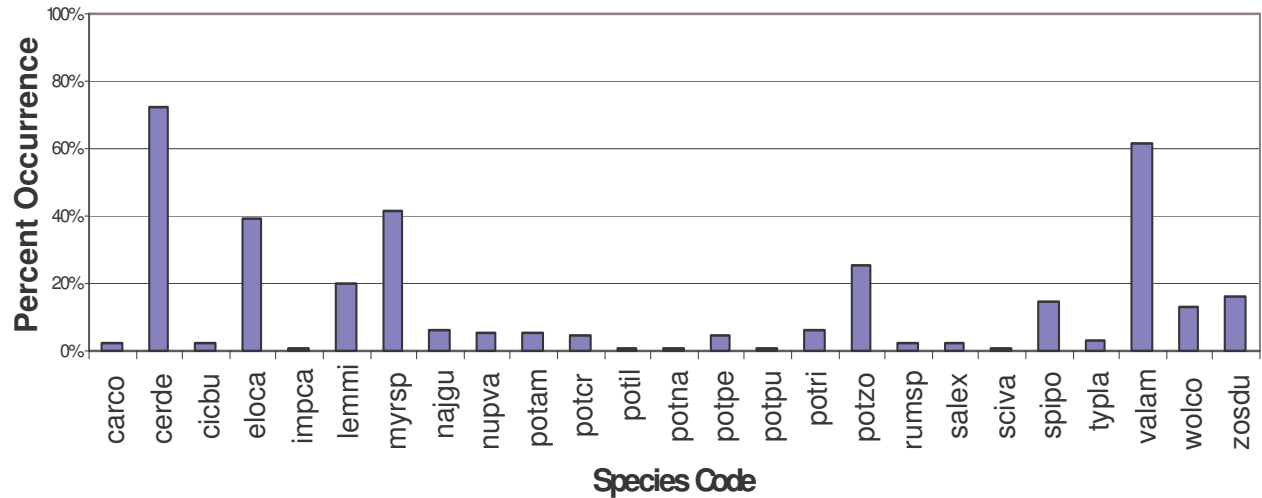


Figure 5. Frequencies of aquatic plant species in Big Roche-a-Cri Lake, 2004

### DENSITY

*Vallisneria americana* was the species with the highest mean density in Big Roche-a-Cri Lake (1.94 on a density scale of 1-4) (Figure 6).

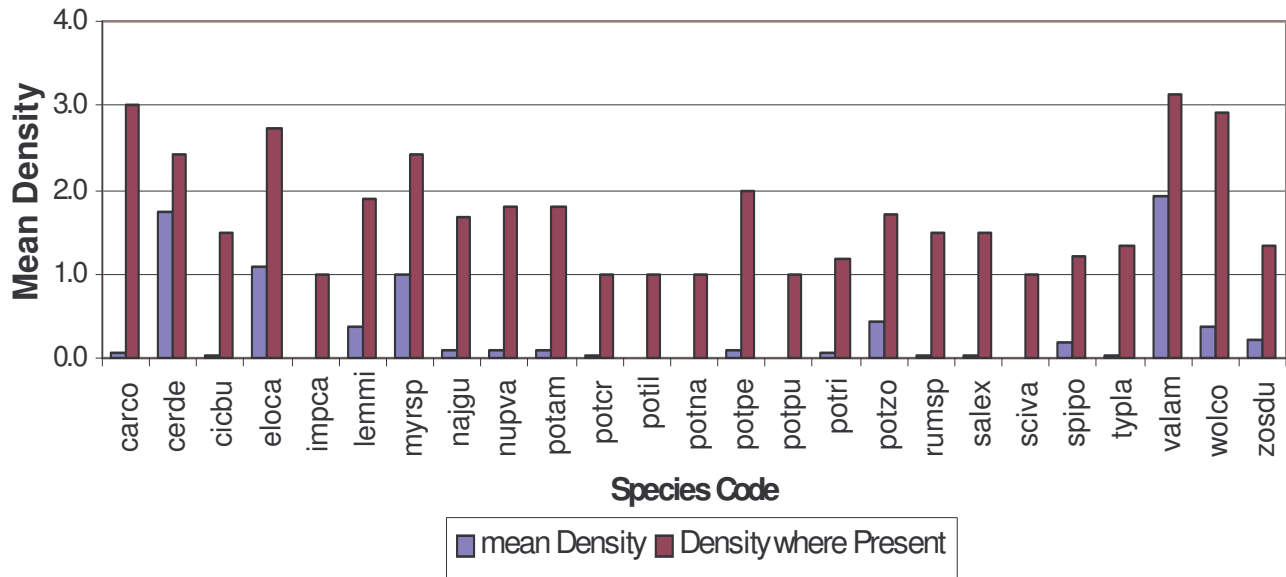
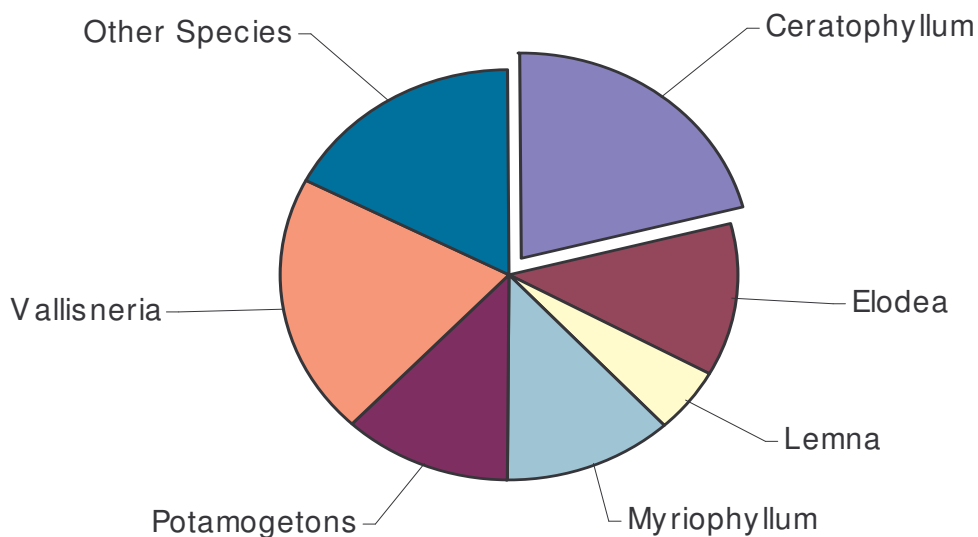


Figure 6. Densities of aquatic plant species in Big Roche-a-Cri Lake, 2004

*Vallisneria americana* had a “mean density where present” of 3.14. Its “mean density where present” indicates that, where *V. americana* occurred, it exhibited a growth form of above average density in Big Roche-a-Cri Lake (Figure 6). *Carex comosa*, *Elodea canadensis* and *Wolffia columbiana* also had “densities where present” of 2.5 or more, indicating that they also exhibited a growth form of above average density (Figure 6, Appendix II).

### DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community (Appendix III). Based on the Dominance Value, *Ceratophyllum demersum* was the dominant aquatic plant species in Big Roche-a-Cri Lake (Figure 7). *Vallisneria americana* was sub-dominant. The exotic species, *Myriophyllum spicatum*, was tied with *Elodea canadensis* as the third ranked species within the plant community.



**Figure 7. Dominance within the macrophyte community, of the most prevalent aquatic macrophytes in Big Roche-a-Cri Lake, 2004.**

### DISTRIBUTION

*Ceratophyllum demersum* was dominant species in the 0-1.5ft depth zone and the most frequently occurring species in the 1.5-10ft depth zone (Figure 8, 9). *C. demersum* occurred at its highest frequency and density in the 5-10 ft depth zone (Figure 8, 9). *C. demersum* and *Vallisneria americana* shared dominance in the 10-20ft depth zone (Figure 8, 9). These two species could also be considered to share dominance in the 1.5-10 ft depth zone since one was the most frequently occurring and the other had the

highest mean density.

*Myriophyllum spicatum*, the exotic species, occurred at its highest density and frequency in the 5-10ft depth zone (Figure 8, 9).

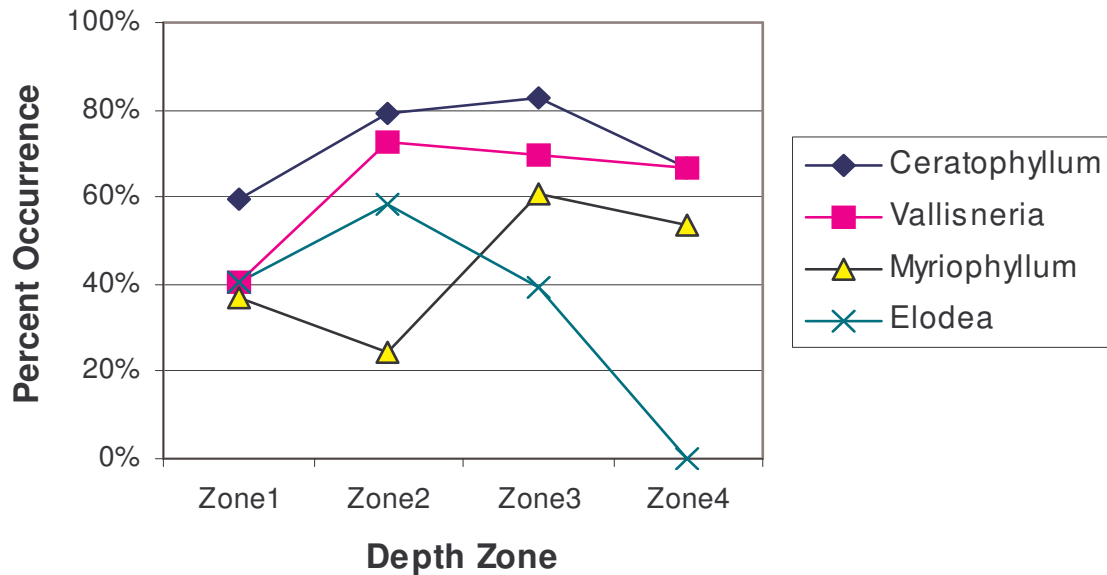


Figure 8. Frequency of occurrence of prevalent macrophytes in Big Roche-a-Cri Lake, by depth zone, 2004.

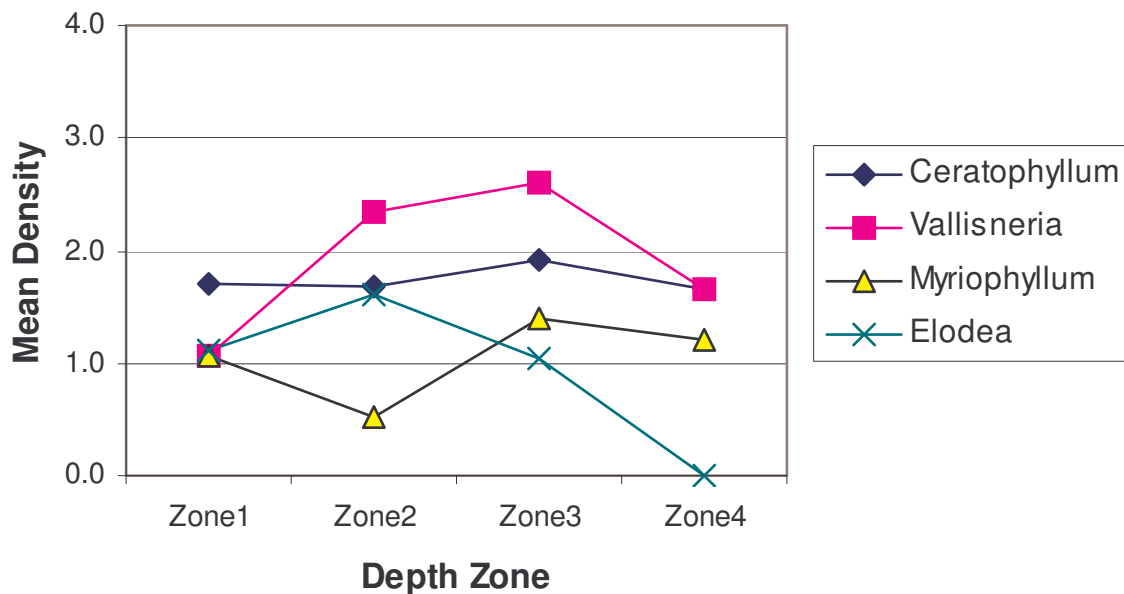


Figure 9. Density of prevalent macrophytes in Big Roche-a-Cri Lake by depth zone, 2004.



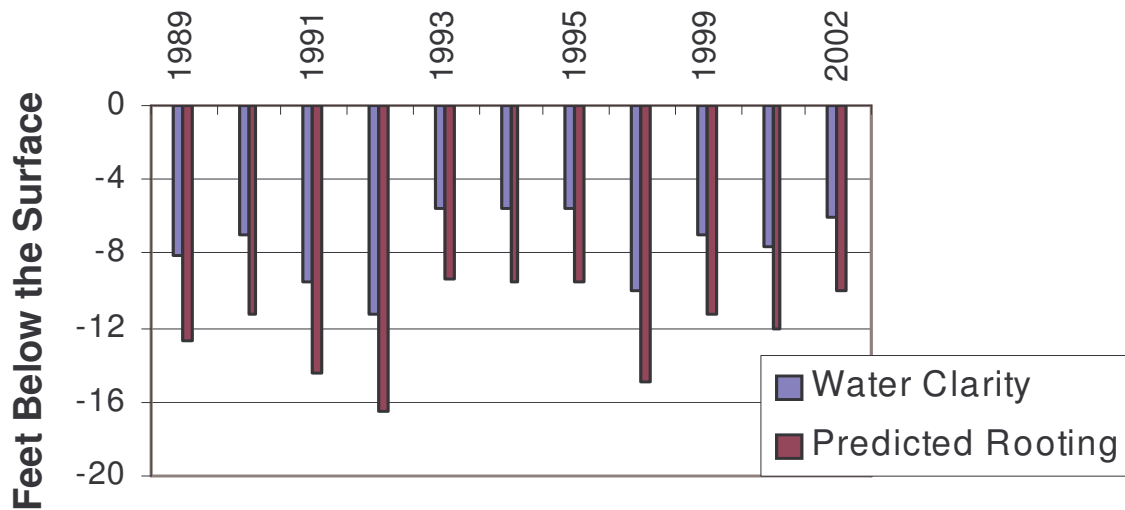
Aquatic plants occurred throughout Big Roche-a-Cri Lake, at 87% of the sampling sites (85% with rooted vegetation), to a maximum rooting depth of 13 feet at which *Vallisneria americana* occurred. *Ceratophyllum demersum* occurred at 14.5 ft, but is not a truly rooted plant and can float in the water column. This allows *C. demersum* to occur in water deeper than the maximum rooting depth based on water clarity.

- 1) At the dam end, 80% of the sites were vegetated, *Vallisneria americana* was dominant and *Myriophyllum spicatum* (Eurasian watermilfoil) was ranked third in dominance.
- 2) In the mid-portion of the lake, 96% of the sites were vegetated, *Ceratophyllum demersum* was dominant and *Myriophyllum spicatum* (Eurasian watermilfoil) was ranked third in dominance, tied with *Elodea canadensis*.
- 3) At the east end, 94% of the sites were vegetated, *Elodea canadensis* was dominant and *Myriophyllum spicatum* (Eurasian watermilfoil) was only scattered.

Secchi disc readings are used to calculate a predicted maximum rooting depth for plants in a lake (Dunst 1982).

**Based on the 2002 Secchi disc clarity, the predicted maximum rooting depth in Big Roche-a-Cri Lake would be 10 ft (Figure 10).**

This maximum rooting depth is greater than the predicted maximum rooting depth based on water clarity (Figure 10). This may be due to better water clarity early in the season when plants are beginning to elongate towards the surface.

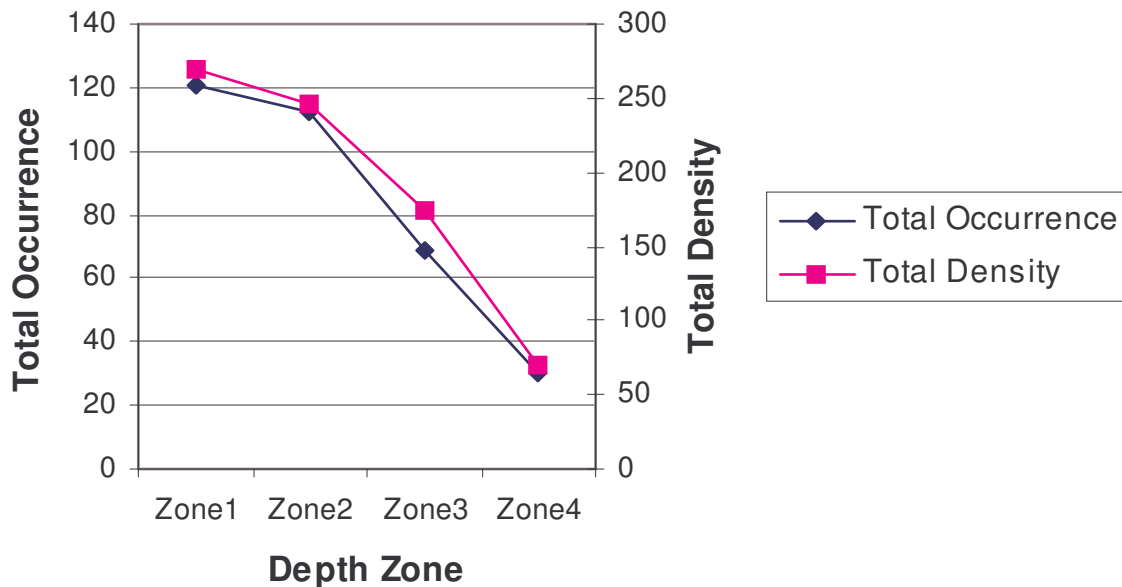


**Figure 10. Predicted maximum rooting depth in Big Roche-a-Cri Lake, based on water clarity, 1989-2002.**

The dominant species were found throughout the lake, but some abundant and common species were not distributed throughout the lake. *Myriophyllum spicatum* was abundant (41% occurrence) and found mostly west of the Highway 13 bridge. Many common species were found only in the east end of the lake:

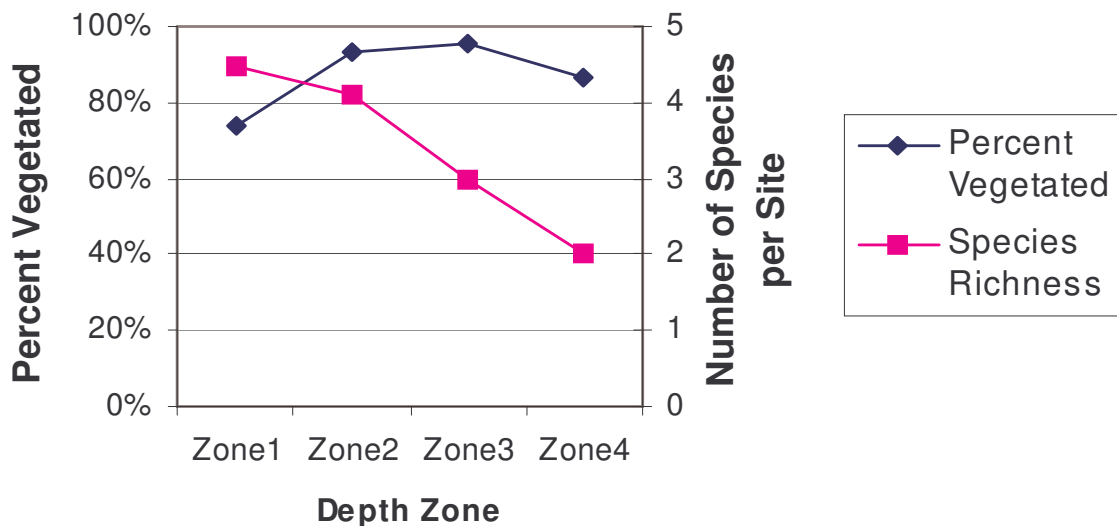
- 1) *Elodea canadensis* (39% occurrence) found only in the east  $\frac{3}{4}$  of the lake
- 2) *Lemna minor*, *Potamogeton zosteriformis* and *Spirodela polyrhiza* were found only in the east half of the lake.
- 3) *Wolffia columbiana* was only found in the east basin, east of the Highway 13 bridge.

The highest total occurrence and total density of plant growth was recorded in the 0-1.5ft depth zone (Figure 11). Total plant occurrence and density declined with increasing depth.



**Figure 11. Total occurrence and total density of plants in Big Roche-a-Cri Lake by depth zone.**

The greatest species richness (mean number of species per site) was also found in the 0-1.5 ft. depth zone; the highest percentage of vegetated sites was in the 5-10ft depth zone (Figure 12).



**Figure 12. Percentage of vegetated site and species richness in Big Roche-a-Cri Lake, by depth zone, 2004.**

Lake-wide species richness was 4.57 species per sample site.

### THE COMMUNITY

Simpson's Diversity Index was 0.87, indicating good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) for Big Roche-a-Cri Lake (Table 9) is 45. This value is below average quality for lakes in Wisconsin and in the lowest quartile of lakes in the North Central Region. The highest value for this index is 70.

**Table 9. Aquatic Macrophyte Community Index, Big Roche-a-Cri, 2004**

Category	Parameter	Value
Maximum Rooting Depth	3.9 meters	7
% Littoral Zone Vegetated	87%	10
Simpson's Diversity	0.886	8
# of Species	25	9
Exotic Species	13% Relative Freq.	4
% Submergent Species	61% Relative Freq.	6
% Sensitive Species	0% Relative Freq.	1
Totals		45

The presence of two exotic species and the lack of sensitive species are limiting the quality of Big Roche-a-Cri Lake.

The Average Coefficient of Conservatism for Big Roche-a-Cri Lake was in the lowest quartile for all Wisconsin lakes and lakes in the North Central Hardwood Region (Table 10). This suggests that the aquatic plant community in Big Roche-a-Cri Lake is among the group of lakes in Wisconsin and the North Central Hardwoods Region most tolerant of disturbance. This is likely due to selection by past disturbance.

The Floristic Quality Index of the plant community in Big Roche-a-Cri Lake was below average for Wisconsin lakes and above average for lake in the North Central Hardwood Region (Table 10). This indicates that the plant community in Big Roche-a-Cri Lake is as close to an undisturbed condition as the average lake in Wisconsin or the North Central Hardwood Region. This suggests that the aquatic plant community in Big Roche-a-Cri has been impacted by an above average amount of disturbance.

**Table 10. Floristic Quality and Coefficient of Conservatism of Big Roche-a-Cri Lake, Compared to Wisconsin Lakes and North Central Wisconsin Lakes.**

	Average Coefficient of Conservatism †	Floristic Quality ‡	Based on Relative Frequency	Based on Dominance Value
Wisconsin Lakes	5.5, 6.0, 6.9 *	16.9, 22.2, 27.5		
NCHR	5.2, 5.6, 5.8 *	17.0, 20.9, 24.4		
Big Roche-a-Cri Lake - 2004	4.42	21.064	19.57	19.52

\* - Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile.

† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

‡ - Lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

These values were based only on the presence or absence of tolerant and intolerant species; the frequency or dominance of these tolerant or intolerant species within the plant community was not taken into consideration. The Floristic Quality Index was recalculated by weighting each species coefficient with its relative frequency and dominance value. The resulting values indicate that Big Roche-a-Cri Lake was in the lowest quartile for the state and the region, in the group of lakes farthest from an undisturbed condition.

Disturbances can be of many types:

- 1) Physical disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
- 2) Indirect disturbances are the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
- 3) Biological disturbances include competition from the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by a fish or wildlife population.

Major disturbances in Big Roche-a-Cri Lake include shoreline development, past herbicide treatments, invasion of exotic species and plant harvesting.

### **Comparison of 1964, 1996 and 2004 Aquatic Plant Assessments**

The 1964 and 1996 plant surveys were not quantitative surveys using the same methods as the 2004 plant study. The earlier surveys were qualitative, not designed to record all species, but possibly just to characterize the common species.

In 1964, a simple species list was made and the dominant species was identified. The 1964 assessment found that curly-leaf pondweed was the dominant species, with sago pondweed, flat-stem pondweed and wild celery also present.

In 1996, Big Roche-a-Cri Lake was divided into 3 areas and qualitative assessments of the plant communities were made within each area. The species in each area were characterized as scattered, common, abundant or thick. Because of the different methods, direct comparisons can not be made, but some observations can be compared.

The total number of species and number of species recorded in each area increased between 1964 and 1996 and again between 1996 and 2004 (Table 11). This is likely due to increasingly more rigorous studies.



**Table 11. Big Roche-a-Cri Lake Aquatic Plant Species, 1964-2004**

1964	1996	2004
<u>Emergent Species</u>	<u>Emergent Species</u>	<u>Emergent Species</u>
		<i>Carex comosa</i> <i>Cicuta bulbifera</i> <i>Impatiens capensis</i> <i>Rumex</i> <i>Salix exigua</i> <i>Scirpus validus</i> <i>Typha latifolia</i>
<u>Floating-leaf Species</u>	<u>Floating-leaf Species</u>	<u>Floating-leaf Species</u>
	<i>Nuphar variegata</i>	<i>Lemna minor</i> <i>Nuphar variegata</i> <i>Spirodela polyrhiza</i>
<u>Submergent Species</u>	<u>Submergent Species</u>	<u>Submergent Species</u>
	<i>Ceratophyllum demersum</i> <i>Elodea canadensis</i> <i>Myriophyllum sibiricum</i>	* <i>Ceratophyllum demersum</i> <i>Elodea canadensis</i>  <i>Myriophyllum spicatum</i> <i>Najas guadalupensis</i> <i>Potamogeton amplifolius</i> <i>Potamogeton crispus</i> <i>Potamogeton illinoensis</i> <i>Potamogeton natans</i>
* <i>Potamogeton crispus</i>	<i>Potamogeton crispus</i>	
	<i>Potamogeton nodosus</i>	
<i>Potamogeton pectinatus</i>		<i>Potamogeton pectinatus</i> <i>Potamogeton pusillus</i> <i>Potamogeton richardsonii</i> <i>Potamogeton zosteriformis</i>
<i>Potamogeton zosteriformis</i>	<i>Potamogeton richardsonii</i> <i>Potamogeton zosteriformis</i>	
<i>Vallisneria americana</i>	* <i>Vallisneria americana</i> <i>Zosterella dubia</i>	<i>Vallisneria americana</i> <i>Zosterella dubia</i> Filamentous algae

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\* - Dominant species

The dominant species in Big Roche-a-Cri Lake changed from *Potamogeton crispus* in 1964 to *Vallisneria americana* in 1996 to *Ceratophyllum demersum* in 2004.

Since a quantitative survey was not conducted in 1996, the only comparison that can be made is in the qualitative assessments of each species in each of the areas delineated in 1979 (Appendix V).

In area 1, upstream and east of Highway 13;

- 1) 8 species were recorded in 1996 and 21 species were recorded in 2004.
- 2) In 1996, *Zosterella dubia* was characterized as thick.

- 3) *Elodea canadensis* as common-to-abundant.
- 4) *Potamogeton zosteriformis* as scattered to abundant
- 5) *Ceratophyllum demersum*, *Myriophyllum sibiricum*, *Potamogeton crispus*, *P. nodosus*, *P. richardsonii* all as scattered.
- 6) *Nuphar variegata* was present in one small bed.

In 2004, *Zosterella dubia* is now only scattered. *Ceratophyllum demersum* and *Elodea canadensis* are now thick and dense, having increased to the dominant and subdominant species in area 1.

Species that have changed in this area are:

- 1) In 2004, *Zosterella dubia* is now only scattered.
- 2) *Ceratophyllum demersum* and *Elodea canadensis* are now thick and dense, having increased to the dominant and subdominant species.
- 3) Three species of duckweed are now found in area 1 and are abundant (*Lemna minor*, *Spirodela polyrhiza*, *Wolffia columbiana*.)
- 4) Two species are no longer found in area 1 (*Myriophyllum sibiricum*, *Potamogeton nodosus*).

Area 2 was delineated as the mid-area of the lake, west of Highway 13.

- 1) 4 species were recorded in 1996 and 15 were recorded in 2004.
- 2) In 1996, the species in area 2 were characterized as: *Vallisneria americana* was thick along the entire shore.
- 3) *Elodea canadensis* was abundant to thick.
- 4) *Potamogeton zosteriformis* was scattered to common.
- 5) *Ceratophyllum demersum* was scattered.

Changes in 2004 were:

- 1) In 2004, *Ceratophyllum demersum* had become thick and dense, the dominant species.
- 2) *Vallisneria americana* had decreased to abundant and was sub-dominant,
- 3) Three new species in the area were common, *Lemna minor*, *Wolffia columbiana*, *Zosterella dubia*.
- 4) another new species in this area, the non-native *Myriophyllum spicatum* is now abundant and dense.

Area 3 is the area close to the dam.

- 1) In 1996, 4 species were recorded and in 2004, 11 species were recorded in this area.
- 2) The species in this area in 1996 were characterized as: *Vallisneria americana* was thick all along the shore.
- 3) *Potamogeton zosteriformis* was scattered to common.
- 4) *Ceratophyllum demersum* and *Elodea canadensis* were scattered.

The changes in 2004 are:

- 1) *Ceratophyllum demersum* has become abundant and is the sub-dominant species.
- 2) The exotic species *Myriophyllum spicatum* has been introduced and is now common and dense.

## V. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Big Roche-a-Cri Lake is a mesotrophic lake with good water quality and fair-to-poor water clarity. This trophic state should support moderate plant growth and occasional algae blooms. Filamentous algae occurred at 18% of sites, common in the 0-5ft depth zone. More than one-quarter of the sites had filamentous algae in the shallowest zone. Filamentous algae declined with increasing depth. Thick films of planktonic algae were found at 37% of the sites, abundant in the 0-10ft depth zone and common in the 10-20ft depth zone.

Phosphorus (nutrients) increased substantially from 1995 to 2002. Chlorophyll decreased in this same time period. Increased nutrients usually result in increased algae (chlorophyll), but the nutrients could also be used to feed increased plant growth or increased filamentous algae which is not measured in the chlorophyll sampling techniques. Water clarity decreased from 1989 to 2002.

The large ratio of watershed size to lake size tends to result in a concentrating of the nutrients into the lake. This is common with impoundments. Agricultural use is found on nearly one-third of the watershed, contributing 56% of the nutrient phosphorus load. The annual phosphorus load to Big Roche-a-Cri Lake was estimated at 826 pounds per year.

Adequate nutrients (mesotrophic status), the moderately-hard water, the shallow depth in most of the lake and the gradually sloped littoral zone favor plant growth in Big Roche-a-Cri Lake. The dominance of high-density sand sediments in Big Roche-a-Cri Lake could limit the density of plant growth. Favorable silt and muck sediments occur mainly in the east end of the lake.

There is a long history of chemical use for treating aquatic plant growth and algae in Big Roche-a-Cri Lake, 1959-1987. In some years, up to 10 treatments a year were conducted and up to one-quarter of the lake was treated at a time.

- 1) Two products that are now banned because of their toxicity had been used for 7 years.
- 2) Broad-spectrum chemicals have been used for 13 years.
- 3) Two chemicals that do not biodegrade, but build up in the sediment, resulting in toxic sediment have been used
- 4) Chemicals that are toxic to young fish had been used for 11 years.

Since 1988, mechanical harvesting has been conducted in Big Roche-a-Cri Lake and has removed more than 30 million pounds of plant material. This removal of vegetation would help with nutrient reduction although, impoundments have continuous nutrient input from the river and watershed. In order to counter the estimated yearly 826-pound phosphorus load to Big Roche-a-Cri, harvesting would have to remove 115-257 tons of plant material a year (based on tissue phosphorus concentrations of aquatic plants in area lakes). Big Roche-a-Cri has been removing an average of 694 tons per year (1260 tons per year since the purchase of a second harvester) and should be able to counteract this yearly phosphorus load.

Big Roche-a-Cri Lake has some protection by natural shoreline cover (wooded, shrub, native herbaceous growth). Wooded cover was encountered most frequently and had the highest mean coverage (45%). However, disturbed shoreline was also frequently encountered and covered 31% of the shore. One type of disturbed cover, cultivated lawn, occurred at 41% of the sample sites and covered 20% of the shoreline. Areas with cultivated lawn impact the lake through increased run-off of lawn fertilizers, pesticides and pet wastes into the lake. The short blades and root systems of mowed lawn does not effectively slow run-off to the lake or absorb water, nutrients and toxics as well. Expanding the buffer of natural vegetation along the shore will help prevent shoreline erosion and help reduce additional nutrient/chemical run-off that can add to algae growth and sedimentation of the lake bottom.

### **2004 Plant Community**

Aquatic plants occurred at 87% of the sites (85% with rooted vegetation), to a maximum depth of 13 feet. This actual maximum rooting depth is greater than the predicted maximum rooting depth, based on water clarity. This could be due to better clarity, early in the season as the plants are beginning to elongate toward the surface.

The highest total occurrence of plants, highest total density of plants and the greatest species richness occurred in the 0-1.5ft depth zone. The greatest percentage of vegetated sites occurred in the 1.5-10ft depth zone. The mid-portion of the lake, where *Ceratophyllum demersum* was dominant, had the greatest coverage of plant growth. The west end at the dam, where *Vallisneria americana* was dominant, had the lowest coverage of plant growth.

Twenty-four species were recorded in Big Roche-a-Cri Lake in 2004. *Ceratophyllum demersum* was the dominant plant species in Big Roche-a-Cri Lake due to its high frequency of occurrence, especially in the 0-1.5ft depth zone, occurring at nearly three-quarters of all sample sites. *Vallisneria americana* was sub-dominant and grew at high densities, *C. demersum* and *V. americana* dominated all depth zones. Besides *V. americana*, three other species exhibited a dense grow form in Big Roche-a-Cri Lake: *Carex comosa*, *Elodea canadensis*, *Wolffia columbiana*. Of these species, only *E. canadensis* was also a frequently occurring species.

*Myriophyllum spicatum*, the exotic Eurasian watermilfoil, recently invaded Big Roche-a-Cri Lake. It was abundant (41% frequency), but more abundant west of Highway 13. Although frequently occurring, Eurasian watermilfoil grew at average densities in Big Roche-a-Cri Lake and was only scattered in the east basin. *M. spicatum* was more prevalent in the 5-10' depth zone and ranked third in dominance in Big Roche-a-Cri Lake, tied with *Elodea canadensis*.

The other exotic species, *Potamogeton crispus*, has been recorded in Big Roche-a-Cri Lake since 1964. In 2004, *P. crispus* occurred at a low frequency and density in Big Roche-a-Cri Lake. It is ranked 14<sup>th</sup> in dominance and ties for 14<sup>th</sup> with *P. pectinatus*.

The Aquatic Macrophyte Community Index (AMCI) for Big Roche-a-Cri Lake was 45,

indicating that the quality of the plant community in Big Roche-a-Cri Lake is below average for Wisconsin lakes. Simpson's Diversity Index (0.87) indicates that the plant community had a good diversity of species. Species Richness in Big Roche-a-Cri Lake was 4.57 species per sample site.

The Average Coefficient of Conservatism and the Floristic Quality Index suggests that Big Roche-a-Cri Lake is among the small group of lakes (25%) in the state and region most tolerant of disturbance and farthest from an undisturbed condition. This is likely due to a high level of disturbance as compared to other lakes in Wisconsin and in the North Central Hardwoods Region of Wisconsin. Disturbances to Big Roche-a-Cri Lake could include past chemical treatments, development of the shorelines, the invasion of exotic species (*Myriophyllum spicatum*, *Potamogeton crispus*) and mechanical harvesting.

### **Changes 1964-2004**

Qualitative comparisons of the 1964, 1996 and 2004 aquatic plant communities were used to determine changes in the plant community (Appendix V). Of the 3 areas the lake had been divided into:

- 1) Species that are tolerant of lower water clarity have increased: *Elodea canadensis* in one area, duckweed species (*Lemna minor*, *Wolffia columbiana* and *Spirodela polyrhiza*) in one-two areas, *Ceratophyllum demersum* in all three areas (Appendix V).
- 2) The non-native watermilfoil (*Myriophyllum spicatum*) has been introduced and increased in colonization throughout the west portion of the lake (Appendix V).
- 3) The introduced milfoil may be out-competing native species: the 1996 dominant *Vallisneria americana* has decreased in one area two native species (*Potamogeton nodosus* and *Myriophyllum sibiricum* (native watermilfoil)) appear to have disappeared from the lake (Appendix V).

Overall changes:

- 4) The dominant species have changed from *Potamogeton crispus* (curly-leaf pondweed) in 1964 to *Vallisneria americana* in 1996. Harvesting early in the season may have controlled the exotic curly-leaf pondweed. This allowed *V. americana* to become dominant as the water clarity increased due to nutrient removal.
- 5) Dominance of species changed again. From the 1996 dominant *Vallisneria americana* there was a shift to *Ceratophyllum demersum* in 2004. The dominance of *C. demersum* may have increased due to declining water quality or due to its ability to compete with the Eurasian watermilfoil invasion. Since *C. demersum* is not a rooted plant, it floats in the water column just under the surface and is therefore not dependent on light availability to the bottom of the lake or being subjected to competition for rooting space.
- 6) The increase in other species may also indicate declining water clarity: *Elodea canadensis* is tolerant of lower light, the three duckweed species (*Lemna minor*, *Spirodela polyrhiza* and *Wolffia columbiana*) float on the water surface and are not dependent on good water clarity.

## VI. CONCLUSIONS

Big Roche-a-Cri Lake is a mesotrophic lake with good water quality and fair-to-poor water clarity. Filamentous algae was common in the 0-5ft depth zone. Thick films of planktonic algae are also common through out the lake, abundant in the 0-10ft dpeth zone.

The aquatic plant community is characterized by below average quality for Wisconsin lakes, good species diversity and impacted by high levels of disturbance. Big Roche-a-Cri Lake is within the 25% of lakes in the state most tolerant of disturbance and furthest from an undisturbed condition. Disturbances include invasions of exotic species, boat traffic, shoreline development, harvesting and past herbicide treatments.

The aquatic plant community colonized more than three-quarters of the littoral zone to a maximum depth of 13 feet. The 0-1.5ft depth zone supported the most abundant growth of plants and the 1.5-5ft depth zone supported the greatest coverage of aquatic plant growth. The middle portion of the impoundment is where the greatest coverage of aquatic plants was found.

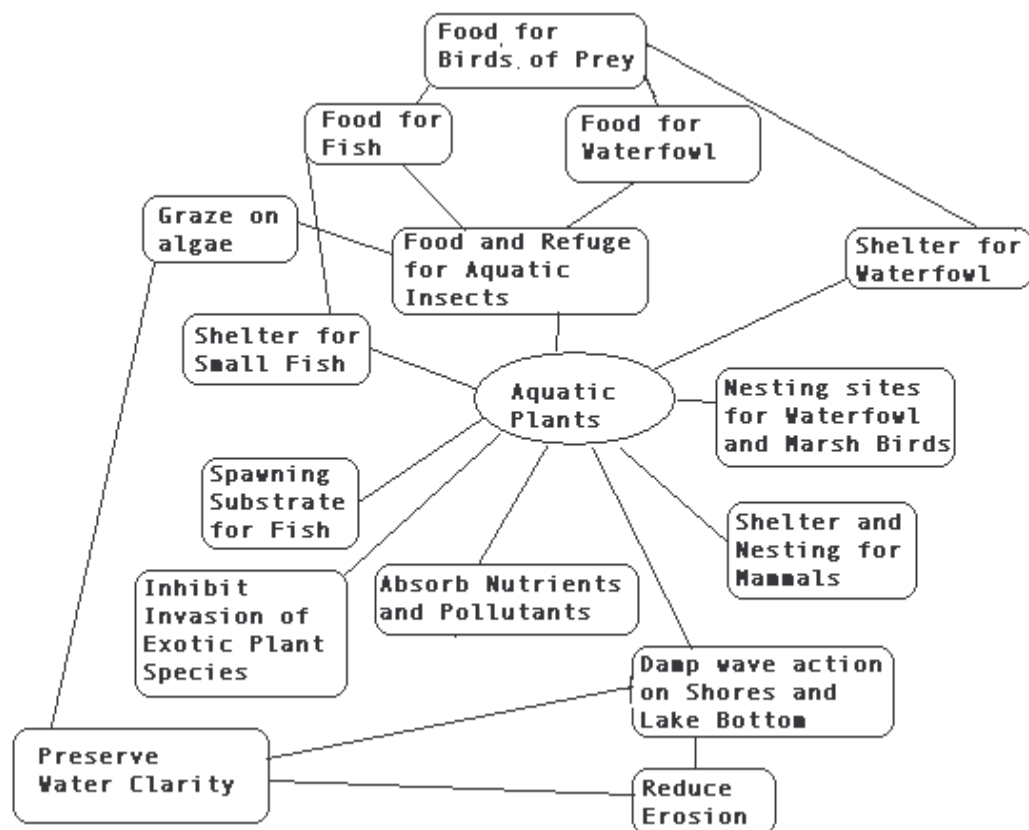
*Ceratophyllum demersum* is the dominant species within the plant community, especially in the 0-1.5ft depth zone. *Vallisneria americana* was sub-dominant, especially in the west end, near the dam. These two species dominate all depth zones.

The recently invaded *Myriophyllum spicatum* was abundant, occurring at nearly half of the sample sites and found at an average density. *M. spicatum* was more abundant in the 5-10' depth zone and in the portion of the lake west of Highway 13..

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in

- 1) improving water quality
- 2) providing valuable habitat resources for fish and wildlife
- 3) resisting invasions of non-native species and
- 4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.





- 1) Aquatic plant communities improve water quality in many ways:
  - they trap nutrients, debris, and pollutants entering a water body;
  - they absorb and break down some pollutants;
  - they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms;
  - they remove nutrients that would otherwise be available for algae blooms (Engel 1985).

2) Aquatic plant communities provide important fishery and wildlife resources. Plants and algae start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish (Table 12). Plant cover within the littoral zone of Big Roche-a-Cri Lake is 87%, which is slightly high for the ideal coverage (25-85%) to support a balanced fishery.

Compared to non-vegetated lake bottoms, macrophyte beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Additionally, mixed stands of macrophytes support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Macrophyte beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).

## **Management Recommendations**

- 1) Reinvolve the Lake District in water quality monitoring through the Self-Help Volunteer Lake Monitoring Program.
- 2) Chemical treatments for plant growth are not recommended in Big Roche-a-Cri Lake due to the undesirable side effects of chemical treatments.
  - a) The decaying plant material releases nutrients that feed algae growth that further reduce water clarity.
  - b) The decaying material also enriches the sediments at the site.
  - c) The herbicides are toxic to an important part of a lake food chain, the invertebrates.
  - d) Broad-spectrum treatments would open up areas that would be vulnerable to the spread of the exotic species.
- 3) Restore natural shoreline restoration. Disturbed shoreline covers nearly one-third of the shore and mowed lawn alone covers nearly one-quarter of the shore.
  - c) Unmowed native vegetation reduces shoreline erosion and run-off into the lake and filters the run-off that does enter the lake thus reducing nutrient inputs.
  - d) Shoreline restoration could be as simple as leaving a band of natural vegetation around the shore by discontinuing mowing.
  - e) Restoration could be as ambitious as extensive plantings of attractive native wetland species in the water and native grasses, flowers, shrubs and trees on the near shore area.
- 4) Fine-tune the harvesting plan. Plan should be designed to remove nutrients, target Eurasian watermilfoil, provide navigation and recreation where appropriate, prevent the spread of species that could become overabundant and improve habitat.
  - a) Nutrient reduction. Harvesting removes the nutrients found in the plant tissue and filamentous algae mats. There is evidence that mechanical harvesting may already to be reducing filamentous algae and nutrients. The 0-1.5ft depth zone has the highest density and occurrence of plant growth, but is not practical for mechanical harvesting. Since the density and occurrence of plant growth is nearly as high in the 1.5-5ft depth zone, harvesting the 3-5 ft depth zone would be effective for nutrient removal.
  - b) Target Eurasian watermilfoil. The milfoil can be targeted by conducting an early-season harvest and a late-season harvest that cuts only where the milfoil is colonized, cutting the largest and densest milfoil areas first and cutting deep. The 5-10ft depth zone is the zone where Eurasian watermilfoil is most prevalent and will likely be the area targeted most during the milfoil harvest. Mid-summer harvesting would focus on the other goals of the harvesting plan. The early-season cutting should be conducted when milfoil is almost to the surface and cut near the sediment level without disturbing the sediments. This harvesting will stress the milfoil and open up the top canopy to allow light penetration into the water for the native species. The late-season harvesting would be conducted in September when native plants are going dormant. This cutting would focus on cutting the milfoil before it autofragments in the fall. This autofragmentation is a strategy milfoil has evolved to increase its spread. If curly-leaf pondweed

increases to a nuisance condition, early spring harvesting for this species could be instituted. Skimming off coontail as the harvester is operating will help control this species that is becoming abundant.

- c) Provide navigation and recreation where appropriate. Cutting channels through the areas that have the densest plant growth and cutting to control Eurasian watermilfoil will also aid navigation of the lake. Harvesting in the depth zone greater than 10 feet to maintain an open area for higher speed boat traffic would also aid navigation.
  - d) Prevent the spread of species that could become overabundant. *Vallisneria americana* is one of the few submergent aquatic plants that grow from the base, as grass does. Frequent harvesting in beds of *V. americana* will encourage its growth. Avoid these plant beds when they are not hindering navigation. When *V. americana* is harvested, cut near the sediment, or as deep as the cutter bar extends. The dam end of the lake supports the most *V. americana*. Harvesting the dam end in less than 10 feet should be avoided.
  - e) Improve habitat. The mid-portion of the lake (area 2) and the 5-10ft depth zone have the greatest colonization of plants and this area could be improved the most with channels (not clear-cutting). Cutting channels in this area provides edge needed for habitat and allows the predator fish to better find prey, supporting a more balanced fishery. These open areas are also used by wildlife. The 0-1.5ft depth zone supports the best species richness and diversity. The only harvesting that should be conducted in this zone are channels next to the docks for land owner access.
- 5) Cooperate with programs in the watershed to reduce nutrient inputs to the lake. Currently nearly half of the relatively large watershed is in agriculture.
  - 6) Eliminate the use of lawn fertilizers, both organic and inorganic, on properties around the lake.
  - 7) Investigate the possibility of using periodic winter drawdowns to control Eurasian watermilfoil in the shallow zone.